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A HIGH-VOLTAGE, HIGH-SPEED OSCILLOGRAPH

The Du Mont Type 248-A Oscillograph Employs the Type 5RP-A Tube

By H. MANSBERG†

During the war a peculiar situation arose concerning the high-frequency performance of cathode-ray oscillographs. Circuits were rapidly developed which had bandwidths of the order of ten megacycles, and oscillographs performed well enough in presenting the average-repetitive phenomena with continuous sweeps. However, many applications in radar, nuclear physics, and the industrial fields involved either discontinuous or low-repetition rate patterns with extremely low duty cycles. Since the brightness of an oscillogram is directly related to the repetition rate, in many cases these patterns were almost invisible or not recordable. To prevent the obsolescence of standard cathode-ray oscillographs for these new applications, it became necessary to develop cathode-ray tubes with considerably higher light output. The Type 5RP-A high-voltage cathode-ray tube is a result of this development.[1]

Since the advent of the Type 5RP-A series of cathode-ray tubes, two oscillographs have been developed which utilize the high light output of these tubes. The first, the Du Mont Type 247-A, has been described in the July-August, 1946 (Vol. 8, No. 4) issue of the "Oscillographer." The Type 247-A, though primarily a low-frequency instrument, has considerably extended the useful range of maximum speed visual-and photographic-writing rates.[2] This instrument is employed as a valuable industrial tool for the testing of high-speed mechanical devices such as motors, relays, camera shutters, etc., and as a projection oscillograph in lecture auditoriums.

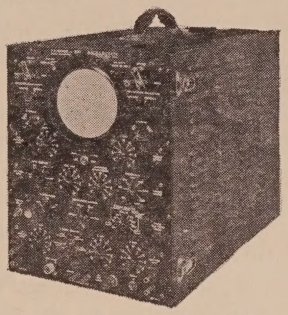

FIGURE 1—The Du Mont Type 248-A Cathode-ray Oscillograph

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[1]See Feldt, R., "High Speed Photographic Recording and Projection Oscillography with the New Du Mont Type 5RP Multiband Tube," The "Oscillographer," Vol. 7, No. 4, (July-August, 1945).

[2]Maximum visual writing rate is defined as the limit value of writing speed at which the average, dark-adapted eye can just discern the trace in a completely darkened room.

Maximum photographic writing rate is defined as the limit value of writing speed at which a photographic recording of density equal to 0.1 above fog may be obtained. This value will depend on the color of the screen material used, its light output, the lens aperture, the sensitivity of the photographic material, and the development procedure.

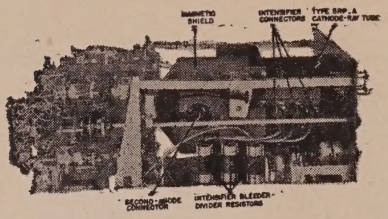

FIGURE 2—Left-side view of indicator chassis of the Type 248-A Oscillograph showing the Type 5RP-A tube and the high-voltage, bleeder-divider resistors

As a result of the ever-increasing demand for instruments which facilitate better observation and recording of high-speed electrical, radio-frequency, and nuclear phenomena, the Du Mont Type 248-A Cathode-ray Oscillograph was developed.

The Type 248-A oscillograph is a modification of the Type 248 oscillograph. Essentially, the modification consists of the substitution of the Type 5RP-A cathode-ray tube for the Type 5JP-A tube and the addition of a high-voltage, bleeder-divider system to supply intensifier voltage to the three intensifier electrodes. Also, the redesign of the cathode-ray tube support, the installation of a magnetic shield, the replacement and rewiring of the cathode-ray tube socket, new deflection-plate and intensifier connectors, and a high-voltage receptacle for connection to the external intensifier-voltage supply. The Du Mont Type 263-A High-Voltage Power Supply is specified as standard equipment to supply the intensifier voltage of 5 to 10 kilovolts.

Figure 1 is a photograph of a section of the interior of the instrument showing the 5RP-A tube and bleeder-divider resistors. This instrument has provisions for the attachment of either the Du Mont Type 2088 Projection Lens or the Type 271-A Oscillograph Record Camera for projection or recording applications.

The Type 248 Oscillograph is especially suitable for such modification because it has been designed primarily as a high-speed oscillograph having the following desirable features:

1. Y-axis amplifier usable to 7 mc with optional signal-delay network
2. X-axis amplifier range extending to 2 mc
3. Z-axis amplifier usable to 7 mc
4. High-speed, vacuum-tube, recurrent and driven sweep circuits
5. Internal timing generator providing 1, 10, and 100 microsecond timing markers
6. An internal trigger generator providing positive and negative pulses of less than one microsecond duration and of peak amplitude between 50 and 100 volts
7. A recently-improved, automatic, beam-control circuit which drives the tube from beam cut-off to high intensity for the full-time duration of the horizontal sweep.

TYPICAL APPLICATIONS: These features plus the high-voltage modification open new fields of application wherever low-duty cycle phenomena of essentially non-repetitive nature are to be observed and recorded:

The rapid testing of electrical cables and transmission lines. A single pulse of one microsecond (or less) duration may be applied to a cable or line while simultaneously initiating the driven sweep of the Type 248-A Oscillograph. By observing the characteristics of the reflections, it is possible to determine the length, the type of termination, the characteristic impedance of the line, and the nature and location of any disturbance along the line. Previously, such tests required the use of highly repetitive pulses to obtain sufficient intensity for observation and recording.[3] Since the amplitude of the pulse required depends upon the length and electrical characteristics of the line and load, pulses of the order of thousands of volts are often necessary to test long lines. Pulses of this order are not readily available at high-repetition rates and therefore it is of consid-

[3]See Ossman, E. A., "Transmission Line Measurements," The "Oscillographer," Vol. 7, No. 3, (May-June, 1945).

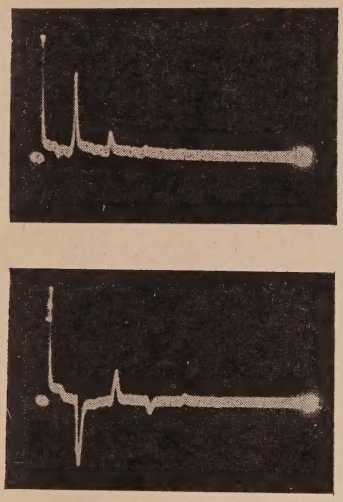

FIGURE 3—Reflections of a Test Pulse Applied to a 900-ft., Artificial Line (a) Open-circuited (b) Short-circuited, note polarity inversion of pulse

erable advantage to have sufficient intensity available with single transients. In addition, the need for synchronization of the oscillograph sweep with the repetition rate of the pulse is eliminated. Figures 2a and 2b show single transients on an artificial transmission line equivalent to approximately 900 feet electrical length.[4] The initial pulse is approximately 0.5 microsecond duration and the length of the sweep is 100 microseconds. A pulse of 45 volts peak was obtained from the differentiated output of an R-C discharge circuit. Figure 2a shows three reflections on an open-circuited line. Note the inversion of polarity of the pulse caused by the short-circuit termination as shown in Figure 2b.

Radar and nuclear-particle-counter applications. As applied to the testing and monitoring of radar and nuclear-particle-counter apparatus in which pulses of extremely sharp rise time are encountered, the additional brightness obtainable from the Type 5RP-A tube facilitates more accurate observation and measurement. In the case of particle-counting, it is possible to obtain continuous-motion recordings for any period of time, thus enabling a more complete study of the recurrence frequency and characteristics of the particles.

Where observation or recording of any type of phenomenon is desired, the region of maximum writing speed of the wave should be of sufficient brightness to be seen or recorded. For a sine wave, the points of greatest writing rate are at the X-axis intercepts. The actual writing speed of the fluorescent spot is the vector sum of the vertical-and horizontal-velocity components. Therefore, wherever maximum writing rates for cathode-ray oscillographs are specified, and it is desired to determine from the data the maximum-frequency sine wave that may be observed or recorded, it is necessary to know the amplitude of the oscillogram, the number of cycles displayed, and the sweep speed and amplitude. The horizontal-velocity component may be kept low by choosing a small-sweep amplitude and a sweep frequency one-tenth or less than that of the signal frequency. The maximum writing speed of the spot will then be very nearly that of the vertical component, and the maximum frequency at that speed will be

$$f=\frac{V_{max}}{2\pi A}$$

where A is equal to one-half of the peak-to-peak amplitude of the sine wave and V_{max} is the given maximum writing speed.

The table on page 4 lists the average expected values of maximum visual- and photographic-writing rates of the Type 248-A Cathode-ray Oscillograph with the Type 5RP2A and 5RP11A tubes. For comparison, a table of maximum writing rates obtained with the Type 248 Cathode-ray Oscillograph is also shown. The marked improvement obtained with the high-voltage modification is apparent.

[4]These photographs were taken with a Du Mont Type 271-A Oscillograph Record Camera using 35 mm film (Eastman Kodak 5211) and an f/3.5 lens. The film was developed in D19 high-speed developer for six minutes. Note the high contrast and printing density obtainable, and the clearly visible detail.

MAXIMUM WRITING RATES FOR THE TYPE 248-A OSCILLOGRAPH
Overall Accelerating Voltage of 12 Kilovolts (external 10 kv-intensifier supply)

Tube Type	Maximum Visual Writing Rate	Maximum Photographic Writing Rates Standard Conditions f=1 M=1	f=3.5 M=4.5/1
5RP2A	38,000 km/sec (1,520 in./microsec)	440 km/sec (17 in./microsec)	100 km/sec (4 in./microsec)
5RP11A	2,600 km/sec (104 in./microsec)	1,000 km/sec (40 in./microsec)	220 km/sec (8.8 in./microsec)

MAXIMUM WRITING RATES FOR THE TYPE 248 OSCILLOGRAPH
Overall Accelerating Voltage of 4 Kilovolts (internal supply)

5JP2A	250 km/sec (10 in./microsec)	2 km/sec (0.08 in./microsec)	0.5 km/sec (0.02 in./microsec)
5JP11A	1,000 km/sec (40 in./microsec)	70 km/sec (3 in./microsec)	16 km/sec (0.6 in./microsec)

Effectively, the Type 248-A oscillograph permits the recording of transients that have writing rates fourteen times higher than those that can be recorded with the Type 248 oscillograph.

The photographic writing rates are given for standard conditions (a lens aperture of f/1, and screen-image-to-negative-image ratio, M, of 1:1), and for a lens aperture of f/3.5 and image-reduction ratio of 4.5:1 such as obtained with a Du Mont Type 271-A Oscillograph Record Camera.

These figures represent average values only, and not the limit speeds for observation and recording. Duplicate or even better results may be obtained, depending upon the cathode-ray tube, ambient light conditions, camera, and photographic material. The recommended photographic procedure employs a 35 mm camera with an f/3.5 (or better) lens aperture, a high-speed recording emulsion such as Eastman Kodak 5211 or 5244, and a high-speed developer. Development time may be extended to the point where background fog becomes objectionable.

The photographic writing rates given in the table for standard conditions maximum speeds for any lens aperture and image-reduction ratio by use of the formula:
may be used to obtain predictions of

$$V=\frac{4\ V_{max}}{f^2\ (1+1/M)^2}$$

where:

V_{max}=writing rate given for f/1 and M=1

f=lens aperture

M=cathode-ray tube image-to-negative-image reduction ratio

From the formula it is seen that the use of an f/1 lens instead of an f/3.5 lens increases the effective writing rate twelve times, while an infinite optical reduction of image size increases the writing rate a maximum limit of four times.

Facilities for the modification of Type 248 cathode-ray oscillographs have been provided at the factory and the new Type 248-A oscillographs are now available. For further information write to the Technical Sales Department of the Allen B. Du Mont Laboratories, Inc., Clifton, New Jersey.

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